Chapter VII

MATCHING IN-AMP CIRCUITS TO MODERN ADCs

Calculating ADC Requirements

The resolution of commercial ADCs is specified in bits. In an ADC, the available resolution equals $(2^n) - 1$, where n is the number of bits. For example, an 8-bit converter provides a resolution of $(2^8) - 1$, which equals 255. In this case, the full-scale input range of the converter divided by 255 will equal the smallest signal it can resolve. For example, an 8-bit ADC with a 5V full-scale input range will have a limiting resolution of 19.6 mV.

In selecting an appropriate ADC to use, we need to find a device that has a resolution better than the measurement resolution but, for economy's sake, not a great deal better.

Table 7-1 provides input resolution and full-scale input range using an ADC with or without an in-amp preamplifier. Note that the system resolution specified in the figure refers to that provided by the converter together with the in-amp preamp (if used). Also, note that for any low level measurement, not only are low noise semiconductor devices needed, but also careful attention to component layout, grounding, power supply bypassing, and often, the use of balanced, shielded inputs.

For many applications, an 8-bit or 10-bit converter is appropriate. The decision to use a high resolution converter alone, or to use a gain stage ahead of a lower resolution converter, depends on which is more important: component cost, or parts count and ease of assembly.

One very effective way to raise system resolution is to amplify the signal first, to allow full use of the dynamic range of the ADC. However, this added gain ahead of the converter will also increase noise. Therefore, it is often useful to add low-pass filtering between the output of an in-amp (or other gain stage) and the input of the converter. Also, in most cases, the system bandwidth should not be set higher than that required to accurately measure the signal of interest. A good rule of thumb is to set the -3 dB corner frequency of the low-pass filter at 10 to 20 times the highest frequency that will be measured.

Adding amplification before the ADC will also reduce the circuit's full-scale input range, but it will lower the resolution requirements (and, therefore, the cost) of the ADC (see Figure 7-1).

For example, using an in-amp with a gain of 10 ahead of an 8-bit, 5 V ADC will increase circuit resolution from 19.5 mV (5 V/256) to 1.95 mV. At the same time, the full-scale input range of the circuit will be reduced to 500 mV (5 V/10).

Converter Type	(2 ⁿ) – 1	Converter Resolution mV/Bit (5 V/((2 ⁿ) - 1))	In-Amp Gain	FS Range (V p-p)	System Resolution (mV p-p)
10-Bit	1023	4.9 mV	1	5	4.9
10-Bit	1023	4.9 mV	2	2.5	2.45
10-Bit	1023	4.9 mV	5	1	0.98
10-Bit	1023	4.9 mV	10	0.5	0.49
12-Bit	4095	1.2 mV	1	5	1.2
12-Bit	4095	1.2 mV	2	2.5	0.6
12-Bit	4095	1.2 mV	5	1	0.24
12-Bit	4095	1.2 mV	10	0.5	0.12
14-Bit	16,383	0.305 mV	1	5	0.305
14-Bit	16,383	0.305 mV	2	2.5	0.153
14-Bit	16,383	0.305 mV	5	1	0.061
14-Bit	16,383	0.305 mV	10	0.5	0.031
16-Bit	65,535	0.076 mV	1	5	0.076
16-Bit	65,535	0.076 mV	2	2.5	0.038
16-Bit	65,535	0.076 mV	5	1	0.015
16-Bit	65,535	0.076 mV	10	0.5	0.008

Table 7-1. Typical System Resolutions vs. Converter Resolution and Preamp (IA) Gain

Matching ADI In-Amps with Some Popular ADCs

Table 7-2 shows recommended ADCs for use with the latest generation of ADI in-amps.

ADI In-Amp	AD8221AR	ADI In-Amp	AD620AR
Small Signal BW:	562 kHz	Small Signal BW:	800 kHz
Noise (e _{NI}):	$8 \text{ nV}/\sqrt{\text{Hz}}$	Noise (e _{NI}):	9 nV/ $\sqrt{\text{Hz}}$
V _{OS} :	60 μV max	V _{OS} :	125 μV max
In-Amp Gain:	10	In-Amp Gain:	10
Maximum Output		Maximum Output	
Voltage Swing:	±3.9 V	Voltage Swing:	±3.9 V
CMR:	90 dB (dc to 60 Hz)	CMR:	73 dB (dc to 60 Hz)
Nonlinearity:	10 ppm max	Nonlinearity:	40 ppm max
Supply Voltage:	$\pm 5 \mathrm{V}$	Supply Voltage:	$\pm 5 \mathrm{V}$
Supply Current:	1 mA max	Supply Current:	1.3 mA max
0.01% Settling Time		0.01% Settling Time	
for 5 V Step:	5 µs	for 5 V Step:	7 μs
0.001% Settling Time		Recommended ADI	ADC#1
for 5 V Step:	6 μs	AD7610, AD7663	
Recommended ADI	ADC#1	Resolution:	16 bits
AD7685, AD7687		Input Range:	Multiple, such as ± 10 V,
Resolution:	16 bits	1 0	±5V,
Input Range:	0 V to 5 V	Sampling Rate:	Up to 250 kSPS
Sampling Rate:	Up to 250 kSPS	S/D Supply:	5 V
S/D Supply:	3 V or 5 V	Power:	2.7 mA @ 100 kSPS
Power:	1.7 mW @ 2.5 V and	Comments:	Allow more and larger
	6 mW typ @ 5 V		input ranges
Comments:	Same package, the AD7685	Recommended ADI	ADC#2
	can be driven through a	AD7895	
	simple RC from the AD8221	Resolution:	12 bits
	directly. The REF pin can be	Input Range:	Multiple, such as ± 10 V.
	driven to fit the ADC range.		± 2.5 V, 0 V to 2.5 V
Recommended ADI	ADC#2	Sampling Rate:	200 kSPS
AD7453/AD7457		S/D Supply:	5 V
Resolution:	12 bits	Power:	2.2 mA @ 100 kSPS
Input Range:	0 V to V _{DD}	Comments:	Allows a bipolar or unipolar
Sampling Rate:	555 kSPS/100 kSPS		input with a single supply
S/D Supply:	3 V or 5 V		
Power:	0.3 mA @ 100 kSPS		
Comments:	Single channel, pseudo		
	differential inputs in a		
	SOT-23 package		

Table 7-2. Recommended ADCs for Use with ADI In-Amps

Table 7-2. Recommended ADCs for Use with ADIIn-Amps (continued)

Small Signal BW:900 kHzNoise (e_{NI}):8 nV/\HzVos:125 μ V maxIn-Amp Gain:5Maximum Output125 μ V maxVoltage Swing: ± 4 VCMR:90 dB (dc to 60 Hz)Nonlinearity:10 ppm maxSupply Voltage: ± 5 VSupply Current:1.2 mA max0.01% Settling Timefor 5 V Step:for 5 V Step:3.2 μ s0.001% Settling Timefor 5 V Step:for 5 V Step:4 μ sRecommended ADI ADC#1AD7661Resolution:I 6 bitsInput Range:0 V to 2.5 VSampling Rate:Up to 100 kSPSS/D Supply:5 VPower:8 mA @ 100 kSPS with referenceComments:Provide a reference voltageRecommended ADI ADC#2AD7940Resolution:14 bitsInput Range:0 V to V _{DD} Sampling Rate:100 kSPSS/D Supply:3 V or 5 VPower:0.83 mA @ 100 kSPSComments:Single channel in an SOT-23MD623ARSmall Signal BW:100 kHzNoise (e_{NI}):35 nV/\HzVosi200 μ V maxIn-Amp Gain:10Maximum OutputVoltage Swing:Voltage Swing: ± 4.5 VCMR:90 dB (dc to 60 Hz)Nonlinearity:50 ppm typSupply Voltage: ± 5 VSupply Current:0.55 mA max	ADI In-Amp	AD8225 Fixed Gain of 5
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S.D. Suppy. $3 \vee$ Power:8 mA @ 100 kSPS with referenceComments:Provide a reference voltageRecommended ADI ADC#2AD7940Resolution:14 bitsInput Range:0 V to V _{DD} Sampling Rate:100 kSPSS/D Supply:3 V or 5 VPower:0.83 mA @ 100 kSPSComments:Single channel in an SOT-23ADI In-AmpAD623ARSmall Signal BW:100 kHzNoise (e _{NI}):35 nV/\HzVos:200 μ V maxIn-Amp Gain:10Maximum OutputVoltage Swing:voltage Swing:±4.5 VCMR:90 dB (dc to 60 Hz)Nonlinearity:50 ppm typSupply Voltage:±5 VSupply Current:0.55 mA max	Sampling Rate.	5V
Fower:Fower:Comments:Forvide a reference voltageRecommended ADI ADC#2AD7940AD7940Resolution:14 bitsInput Range:O V to V _{DD} Sampling Rate:100 kSPSS/D Supply:3 V or 5 VPower:0.83 mA @ 100 kSPSComments:Single channel in an SOT-23ADI In-AmpAD623ARSmall Signal BW:100 kHzNoise (e_{NI}):35 nV/\HzVos:200 μ V maxIn-Amp Gain:10Maximum OutputVoltage Swing: ± 4.5 VCMR:90 dB (dc to 60 Hz)Nonlinearity:50 ppm typSupply Voltage: ± 5 VSupply Current:0.55 mA max	Bower:	8 mA @ 100 kSPS with
Comments:Provide a reference voltageRecommended ADI ADC#2AD7940Imput Range: $0 V to V_{DD}$ Resolution:14 bitsInput Range: $0 V to V_{DD}$ Sampling Rate:100 kSPSS/D Supply: $3 V \text{ or } 5 V$ Power: 0.83 mA @ 100 kSPSComments:Single channel in an SOT-23ADI In-AmpAD623ARSmall Signal BW: 100 kHz Noise (e_{NI}): $35 \text{ nV}/\sqrt{\text{Hz}}$ V_{OS} : $200 \mu V \max$ In-Amp Gain: 10 Maximum Output $Voltage Swing$: $\pm 4.5 V$ CMR: 90 dB (dc to 60 Hz)Nonlinearity: 50 ppm typ Supply Voltage: $\pm 5 V$ Supply Current: 0.55 mA max	I Ower.	reference
Recommended ADI ADC#2AD794014 bitsResolution:14 bitsInput Range: $0 V to V_{DD}$ Sampling Rate:100 kSPSS/D Supply: $3 V \text{ or } 5 V$ Power: 0.83 mA @ 100 kSPSComments:Single channel in an SOT-23ADI In-AmpAD623ARSmall Signal BW: 100 kHz Noise (e_{NI}) : $35 \text{ nV}/\sqrt{\text{Hz}}$ V_{OS} : $200 \mu V \max$ In-Amp Gain: 10 Maximum Output $Voltage Swing$: $\pm 4.5 V$ CMR: $90 \text{ dB} (dc to 60 \text{ Hz})$ Nonlinearity: 50 ppm typ Supply Voltage: $\pm 5 V$ Supply Current: 0.55 mA max	Comments:	Provide a reference voltage
Recommended ADI ADC#2AD 7940Resolution:14 bitsInput Range: $0 V to V_{DD}$ Sampling Rate:100 kSPSS/D Supply: $3 V \text{ or } 5 V$ Power: 0.83 mA @ 100 kSPSComments:Single channel in an SOT-23ADI In-AmpAD623ARSmall Signal BW: 100 kHz Noise (e_{NI}) : $35 \text{ nV}/\sqrt{\text{Hz}}$ V_{OS} : $200 \mu V \text{ max}$ In-Amp Gain: 10 Maximum Output $Voltage Swing$: $\pm 4.5 V$ CMR: 90 dB (dc to 60 Hz)Nonlinearity: 50 ppm typ Supply Voltage: $\pm 5 V$ Supply Current: 0.55 mA max	Becomments.	DC#2
ADJ In-Amp14 bitsInput Range:0 V to V_{DD} Sampling Rate:100 kSPSS/D Supply:3 V or 5 VPower:0.83 mA @ 100 kSPSComments:Single channel in an SOT-23ADI In-AmpAD623ARSmall Signal BW:100 kHzNoise (e_{NI}):35 nV/ \overline{Hz} Vos:200 μ V maxIn-Amp Gain:10Maximum Output100 kBVoltage Swing: ± 4.5 VCMR:90 dB (dc to 60 Hz)Nonlinearity:50 ppm typSupply Voltage: ± 5 VSupply Current:0.55 mA max	AD7940	ADC#2
Input Range:0 V to V_{DD} Sampling Rate:100 kSPSS/D Supply:3 V or 5 VPower:0.83 mA @ 100 kSPSComments:Single channel in an SOT-23 ADI In-AmpAD623AR Small Signal BW:100 kHzNoise (e_{NL}):35 nV/ \sqrt{Hz} Vos:200 μ V maxIn-Amp Gain:10Maximum OutputVoltage Swing: ± 4.5 VCMR:90 dB (dc to 60 Hz)Nonlinearity:50 ppm typSupply Voltage: ± 5 VSupply Current:0.55 mA max	Resolution:	14 hits
Apple FailingSolve (F_{DD})Sampling Rate:100 kSPSS/D Supply:3 V or 5 VPower:0.83 mA @ 100 kSPSComments:Single channel in an SOT-23ADI In-AmpAD623ARSmall Signal BW:100 kHzNoise (e_{NI}):35 nV/ \sqrt{Hz} Vos:200 μ V maxIn-Amp Gain:10Maximum OutputVoltage Swing:voltage Swing: ± 4.5 VCMR:90 dB (dc to 60 Hz)Nonlinearity:50 ppm typSupply Voltage: ± 5 VSupply Current:0.55 mA max	Input Range	$0 V to V_{DD}$
Sompting hard100 hor 5VS/D Supply: $3 V \text{ or } 5 V$ Power: $0.83 \text{ mA} @ 100 \text{ kSPS}$ Comments:Single channel in an SOT-23 ADI In-AmpAD623AR Small Signal BW: 100 kHz Noise (e_{NL}): $35 \text{ nV}/\sqrt{\text{Hz}}$ V_{OS} : $200 \mu V \text{ max}$ In-Amp Gain: 10 Maximum Output $Voltage Swing: \pm 4.5 V$ CMR: $90 \text{ dB} (\text{dc to } 60 \text{ Hz})$ Nonlinearity: 50 ppm typ Supply Voltage: $\pm 5 V$ Supply Current: 0.55 mA max	Sampling Rate:	100 kSPS
Body Supply $5 \times 10^{-5} \text{ M}^2$ Power: $0.83 \text{ mA} @ 100 \text{ kSPS}$ Comments:Single channel in an SOT-23ADI In-AmpAD623ARSmall Signal BW: 100 kHz Noise (e_{NL}): $35 \text{ nV}/\sqrt{\text{Hz}}$ Vos: $200 \mu \text{V}$ maxIn-Amp Gain: 10 Maximum Output $V0$ tage Swing: $\pm 4.5 \text{ V}$ CMR: 90 dB (dc to 60 Hz)Nonlinearity: 50 ppm typ Supply Voltage: $\pm 5 \text{ V}$ Supply Current: 0.55 mA max	S/D Supply:	3 V or 5 V
Comments:Single channel in an SOT-23ADI In-AmpAD623ARSmall Signal BW: 100 kHz Noise (e_{NL}): $35 \text{ nV}/\sqrt{\text{Hz}}$ Vos: $200 \mu \text{V}$ maxIn-Amp Gain: 10 Maximum Output V Voltage Swing: $\pm 4.5 \text{ V}$ CMR:90 dB (dc to 60 Hz)Nonlinearity: 50 ppm typ Supply Voltage: $\pm 5 \text{ V}$ Supply Current: 0.55 mA max	Power:	0.83 mA @ 100 kSPS
ADI In-AmpAD623ARSmall Signal BW: 100 kHz Noise (e_{NI}) : $35 \text{ nV}/\sqrt{\text{Hz}}$ V_{OS} : $200 \mu \text{V}$ maxIn-Amp Gain: 10 Maximum Output V Voltage Swing: $\pm 4.5 \text{ V}$ CMR:90 dB (dc to 60 Hz)Nonlinearity: 50 ppm typ Supply Voltage: $\pm 5 \text{ V}$ Supply Current: 0.55 mA max	Comments:	Single channel in an SOT-23
ADI In-AmpAD623ARSmall Signal BW: 100 kHz Noise (e_{NI}) : $35 \text{ nV}/\sqrt{\text{Hz}}$ V_{OS} : $200 \mu \text{V}$ maxIn-Amp Gain: 10 Maximum Output 10 Voltage Swing: $\pm 4.5 \text{ V}$ CMR:90 dB (dc to 60 Hz)Nonlinearity: 50 ppm typ Supply Voltage: $\pm 5 \text{ V}$ Supply Current: 0.55 mA max		0
ADI In-AmpAD623ARSmall Signal BW: 100 kHz Noise (e_{NI}) : $35 \text{ nV}/\sqrt{\text{Hz}}$ V_{OS} : $200 \mu \text{V}$ maxIn-Amp Gain: 10 Maximum Output 10 Voltage Swing: $\pm 4.5 \text{ V}$ CMR: 90 dB (dc to 60 Hz)Nonlinearity: 50 ppm typ Supply Voltage: $\pm 5 \text{ V}$ Supply Current: 0.55 mA max		
Small Signal BW:100 kHzNoise (e_{NI}) :35 nV/ \sqrt{Hz} V_{OS} :200 μ V maxIn-Amp Gain:10Maximum Output ± 4.5 VVoltage Swing: ± 4.5 VCMR:90 dB (dc to 60 Hz)Nonlinearity:50 ppm typSupply Voltage: ± 5 VSupply Current:0.55 mA max	ADI In-Amp	AD623AR
Noise (e_{NI}) :35 nV/ \sqrt{Hz} V_{OS} :200 μ V maxIn-Amp Gain:10Maximum Output 10 Voltage Swing: ± 4.5 VCMR:90 dB (dc to 60 Hz)Nonlinearity:50 ppm typSupply Voltage: ± 5 VSupply Current:0.55 mA max	Small Signal BW:	100 kHz
V_{OS} : $200 \ \mu V \max$ In-Amp Gain: 10 Maximum Output $voltage Swing$: $\pm 4.5 V$ CMR: $90 \ dB \ (dc \ to \ 60 \ Hz)$ Nonlinearity: $50 \ ppm \ typ$ Supply Voltage: $\pm 5 V$ Supply Current: $0.55 \ mA \ max$	Noise (e _{NI}):	$35 \text{ nV}/\sqrt{\text{Hz}}$
In-Amp Gain:10Maximum OutputVoltage Swing:±4.5 VCMR:90 dB (dc to 60 Hz)Nonlinearity:50 ppm typSupply Voltage:±5 VSupply Current:0.55 mA max	V _{OS} :	200 μV max
Maximum OutputVoltage Swing: $\pm 4.5 V$ CMR:90 dB (dc to 60 Hz)Nonlinearity:50 ppm typSupply Voltage: $\pm 5 V$ Supply Current:0.55 mA max	In-Amp Gain:	10
Voltage Swing: $\pm 4.5 \text{ V}$ CMR:90 dB (dc to 60 Hz)Nonlinearity:50 ppm typSupply Voltage: $\pm 5 \text{ V}$ Supply Current:0.55 mA max	Maximum Output	
CMR:90 dB (dc to 60 Hz)Nonlinearity:50 ppm typSupply Voltage:±5 VSupply Current:0.55 mA max	Voltage Swing:	$\pm 4.5\mathrm{V}$
Nonlinearity:50 ppm typSupply Voltage:±5 VSupply Current:0.55 mA max	CMR:	90 dB (dc to 60 Hz)
Supply Voltage:±5 VSupply Current:0.55 mA max	Nonlinearity:	50 ppm typ
Supply Current: 0.55 mA max	Supply Voltage:	$\pm 5 \text{V}$
	Supply Current:	0.55 mA max
0.01% Settling Time	0.01% Settling Time	
for 5V Step: 20 μs	for 5 V Step:	20 µs

Recommended ADI A	DC#1
AD7866	
Resolution:	12 bits
Input Range:	$0 V$ to $V_{REF} V$ or $0 V$ to
	$2 \times V_{REE} V$
Sampling Rate:	1 MSPS for both ADCs
S/D Supply:	Single, 2.7 V to 5.25 V
Power:	24 mW max at 1 MSPS with
	5V supply 11.4 mW max at
	1 MSPS with 3 V supply
Comments:	Dual, 2-channel, simultaneous
	sampling ADC with a
	serial interface
	DC#2
AD79(2) AD79(4	DC#2
AD/802/AD/804	10 hits
Resolution:	12 DHS
Input Range:	$0 \vee t0 + 2.5 \vee, 0 \vee t0 + 5 \vee,$
O	± 2.5 V, ± 5 V, ± 10 V
Sampling Kate:	600 kSPS for one channel
S/D Supply:	Single, 5 v
Power:	90 mw typ
Comments:	4-channel, simultaneous
	sampling ADC with a
	parallel interface
	DC#2
Recommended ADI A	DC#3
Recommended ADI A AD7863/AD7865	DC#3
Recommended ADI A AD7863/AD7865 Resolution:	14 bits
Recommended ADI A AD7863/AD7865 Resolution: Input Range:	14 bits 0V to +2.5V, 0V to +5V,
Recommended ADI A AD7863/AD7865 Resolution: Input Range:	14 bits 0V to +2.5V, 0V to +5V, ±2.5V, ±5V, ±10V
Recommended ADI A AD7863/AD7865 Resolution: Input Range: Sampling Rate:	14 bits 0V to +2.5V, 0V to +5V, ±2.5V, ±5V, ±10V 175 kSPS for both channels/
Recommended ADI A AD7863/AD7865 Resolution: Input Range: Sampling Rate:	14 bits 0V to +2.5V, 0V to +5V, ±2.5V, ±5V, ±10V 175 kSPS for both channels/ 360 kSPS for one channel,
Recommended ADI A AD7863/AD7865 Resolution: Input Range: Sampling Rate:	14 bits 0V to +2.5V, 0V to +5V, ±2.5V, ±5V, ±10V 175 kSPS for both channels/ 360 kSPS for one channel, respectively
Recommended ADI A AD7863/AD7865 Resolution: Input Range: Sampling Rate: S/D Supply:	14 bits 0V to +2.5V, 0V to +5V, ±2.5V, ±5V, ±10V 175 kSPS for both channels/ 360 kSPS for one channel, respectively Single, 5V
Recommended ADI A AD7863/AD7865 Resolution: Input Range: Sampling Rate: S/D Supply: Power:	14 bits 0V to +2.5V, 0V to +5V, ±2.5V, ±5V, ±10V 175 kSPS for both channels/ 360 kSPS for one channel, respectively Single, 5V 70 mW typ/115 mV typ,
Recommended ADI A AD7863/AD7865 Resolution: Input Range: Sampling Rate: S/D Supply: Power:	14 bits 0V to +2.5V, $0V$ to +5V, $\pm 2.5V$, $\pm 5V$, $\pm 10V$ 175 kSPS for both channels/ 360 kSPS for one channel, respectively Single, $5V$ 70 mW typ/115 mV typ, respectively
Recommended ADI A AD7863/AD7865 Resolution: Input Range: Sampling Rate: S/D Supply: Power: Comments:	14 bits 0V to +2.5V, 0V to +5V, ±2.5V, ±5V, ±10V 175 kSPS for both channels/ 360 kSPS for one channel, respectively Single, 5V 70 mW typ/115 mV typ, respectively 2-/4-channel, respectively,
Recommended ADI A AD7863/AD7865 Resolution: Input Range: Sampling Rate: S/D Supply: Power: Comments:	14 bits 0V to +2.5V, 0V to +5V, ±2.5V, ±5V, ±10V 175 kSPS for both channels/ 360 kSPS for one channel, respectively Single, 5V 70 mW typ/115 mV typ, respectively 2-/4-channel, respectively, simultaneous sampling ADC
Recommended ADI A AD7863/AD7865 Resolution: Input Range: Sampling Rate: S/D Supply: Power: Comments:	14 bits 0V to +2.5V, 0V to +5V, ±2.5V, ±5V, ±10V 175 kSPS for both channels/ 360 kSPS for one channel, respectively Single, 5V 70 mW typ/115 mV typ, respectively 2-/4-channel, respectively, simultaneous sampling ADC with a parallel interface
Recommended ADI A AD7863/AD7865 Resolution: Input Range: Sampling Rate: S/D Supply: Power: Comments: Recommended ADI A	14 bits 0V to +2.5V, 0V to +5V, ±2.5V, ±5V, ±10V 175 kSPS for both channels/ 360 kSPS for one channel, respectively Single, 5V 70 mW typ/115 mV typ, respectively 2-/4-channel, respectively, simultaneous sampling ADC with a parallel interface IDC#4
Recommended ADI A AD7863/AD7865 Resolution: Input Range: Sampling Rate: S/D Supply: Power: Comments: Recommended ADI A AD7890/AD7891/AD7	14 bits 0V to +2.5V, 0V to +5V, ±2.5V, ±5V, ±10V 175 kSPS for both channels/ 360 kSPS for one channel, respectively Single, 5V 70 mW typ/115 mV typ, respectively 2-/4-channel, respectively, simultaneous sampling ADC with a parallel interface DC#4 892
Recommended ADI A AD7863/AD7865 Resolution: Input Range: Sampling Rate: S/D Supply: Power: Comments: Recommended ADI A AD7890/AD7891/AD7 Resolution:	14 bits 0V to +2.5V, 0V to +5V, ±2.5V, ±5V, ±10V 175 kSPS for both channels/ 360 kSPS for one channel, respectively Single, 5V 70 mW typ/115 mV typ, respectively 2-/4-channel, respectively, simultaneous sampling ADC with a parallel interface DC#4 892 12 bits
Recommended ADI A AD7863/AD7865 Resolution: Input Range: Sampling Rate: S/D Supply: Power: Comments: Recommended ADI A AD7890/AD7891/AD7 Resolution: Input Range:	14 bits 0V to +2.5V, 0V to +5V, ±2.5V, ±5V, ±10V 175 kSPS for both channels/ 360 kSPS for one channel, respectively Single, 5V 70 mW typ/115 mV typ, respectively 2-/4-channel, respectively, simultaneous sampling ADC with a parallel interface DC#4 892 12 bits 0V to +2.5V, 0V to
Recommended ADI A AD7863/AD7865 Resolution: Input Range: Sampling Rate: S/D Supply: Power: Comments: Recommended ADI A AD7890/AD7891/AD7 Resolution: Input Range:	14 bits 0V to +2.5V, 0V to +5V, ±2.5V, ±5V, ±10V 175 kSPS for both channels/ 360 kSPS for one channel, respectively Single, 5V 70 mW typ/115 mV typ, respectively 2-/4-channel, respectively, simultaneous sampling ADC with a parallel interface DC#4 892 12 bits 0V to +2.5V, 0V to +4.096 V, 0V to +5V,
Recommended ADI A AD7863/AD7865 Resolution: Input Range: Sampling Rate: S/D Supply: Power: Comments: Recommended ADI A AD7890/AD7891/AD7 Resolution: Input Range:	14 bits 0V to +2.5V, $0V$ to +5V, $\pm 2.5V$, $\pm 5V$, $\pm 10V$ 175 kSPS for both channels/ 360 kSPS for one channel, respectively Single, $5V$ 70 mW typ/115 mV typ, respectively 2-/4-channel, respectively, simultaneous sampling ADC with a parallel interface DC#4 892 12 bits 0V to +2.5V, $0V$ to +4.096 V, $0V$ to +5V, $\pm 2.5V$, $\pm 5V \pm 10V$
Recommended ADI A AD7863/AD7865 Resolution: Input Range: Sampling Rate: S/D Supply: Power: Comments: Recommended ADI A AD7890/AD7891/AD7 Resolution: Input Range: Sampling Rate:	14 bits 0V to +2.5V, $0V$ to +5V, $\pm 2.5V$, $\pm 5V$, $\pm 10V$ 175 kSPS for both channels/ 360 kSPS for one channel, respectively Single, $5V$ 70 mW typ/115 mV typ, respectively 2-/4-channel, respectively, simultaneous sampling ADC with a parallel interface DC#4 892 12 bits 0V to +2.5V, $0V$ to +4.096 V, $0V$ to +5V, $\pm 2.5V$, $\pm 5V \pm 10V$ 117/500/600 kSPS, respectively
Recommended ADI A AD7863/AD7865 Resolution: Input Range: Sampling Rate: S/D Supply: Power: Comments: Recommended ADI A AD7890/AD7891/AD7 Resolution: Input Range: Sampling Rate: S/D Supply:	14 bits 0V to +2.5V, $0V$ to +5V, $\pm 2.5V$, $\pm 5V$, $\pm 10V$ 175 kSPS for both channels/ 360 kSPS for one channel, respectively Single, $5V$ 70 mW typ/115 mV typ, respectively 2-/4-channel, respectively, simultaneous sampling ADC with a parallel interface DC#4 892 12 bits 0V to +2.5V, $0V$ to +4.096 V, $0V$ to +5V, $\pm 2.5V$, $\pm 5V \pm 10V$ 117/500/600 kSPS, respectively Single, $5V$
Recommended ADI A AD7863/AD7865 Resolution: Input Range: Sampling Rate: S/D Supply: Power: Comments: Recommended ADI A AD7890/AD7891/AD7 Resolution: Input Range: Sampling Rate: S/D Supply: Power:	14 bits 0V to +2.5V, $0V$ to +5V, $\pm 2.5V$, $\pm 5V$, $\pm 10V$ 175 kSPS for both channels/ 360 kSPS for one channel, respectively Single, $5V$ 70 mW typ/115 mV typ, respectively 2-/4-channel, respectively, simultaneous sampling ADC with a parallel interface DC#4 892 12 bits 0V to +2.5V, $0V$ to +4.096 V, $0V$ to +5V, $\pm 2.5V$, $\pm 5V \pm 10V$ 117/500/600 kSPS, respectively Single, $5V$ 30/85/60 mW typ, respectively

Table 7-2. Recommended ADCs for Use with ADIIn-Amps (continued)

ADI In-Amp	AD627AR	ADI In-Amp	AD8220AR	
Small Signal BW:	30 kHz	JFET In-Amp		
Noise (e _{NI}):	$38 \text{ nV}/\sqrt{\text{Hz}}$	Small Signal BW:	1000 kHz	
V _{OS} :	200 μV max	Noise (e _{NI}):	$15 \text{ nV}/\sqrt{\text{Hz}}$	
In-Amp Gain:	10	V _{OS} :	1 mV max	
Maximum Output		In-Amp Gain:	10	
Voltage Swing:	$\pm 4.9\mathrm{V}$	Maximum Output		
CMR:	77 dB (dc to 60 Hz)	Voltage Swing:	$\pm 4.8\mathrm{V}$	
Nonlinearity:	100 ppm max	CMRR:	110 dB (dc to 60 Hz)	
Supply Voltage:	$\pm 5 \mathrm{V}$	Nonlinearity:	10 ppm max	
Supply Current:	85 μA max	Supply Voltage:	Dual, $\pm 5 \text{ V}$	
0.01% Settling Time		Supply Current:	1 mA max	
for 5 V Step:	135 µs	0.01% Settling Time		
Recommended ADI	ADC#1	for 5 V step:	5 ms	
AD7923/AD7927		Recommended ADI	ADC#1	
Resolution:	12 bits	AD7610/AD7663		
Input Range:	$0 V$ to V_{REF} or $0 V$ to	Resolution:	16 bits	
	$2 imes V_{\text{REF}}$	Input Range:	$\pm 2.5 \text{ V}, \pm 5 \text{ V}, \pm 10 \text{ V}$	
Sampling Rate:	200 kSPS	Sampling Rate:	250 kSPS for both ADCs	
S/D Supply:	Single, 2.7 V to 5.25 V	S/D Supply:	$\pm 5\mathrm{V}$ to $\pm 15\mathrm{V}$ and $5\mathrm{V}$	
Power:	3.6 mW max @ 200 kSPS	Recommended ADC#2		
	with a 3V supply	AD7321, AD7323, ar	d AD7327	
Comments:	8-/4-channel ADCs,	Resolution:	13 bits	
	respectively, with a serial	Input Range:	$\pm 2.5 \text{ V}, \pm 5 \text{ V}, \pm 10 \text{ V}$	
	interface and channel	Sampling Rate:	500 kSPS	
	sequencer	S/D Supply:	$\pm 5\mathrm{V}$ to $\pm 15\mathrm{V}$ and $+5\mathrm{V}$	
Recommended ADI	ADC#2	Power:	17 mW max at 0.5 MSPS	
AD7920			with ± 15 V, and 5 V supply	
Resolution:	12 bits	Recommended ADI	ADC#3	
Input Range:	0 to V _{DD}	AD7898-3		
Sampling Rate:	250 kSPS	Resolution.	12 hits	
S/D Supply:	2.35 V or 5.25 V	Input Range:	+2.5 V	
Power:	3 mW typ @ 250 kSPS with	Sampling Rate:	220 kSPS	
	3 V supply	S/D Supply:	5V	
Comments:	Single channel, serial ADC in	Power:	22.5 mW max at 220 kSPS	
	6-lead SC70		with 5 V supply	

Table 7-2. Recommended ADCs	for Use with ADI
In-Amps (continued)	

ADI In-Amp Zero Drift In-Amp	AD8230RZ	AD Hig	OI In-Amp gh Speed Prograr	AD8250/AD8251 nmable Gain In-Amp
Small Signal BW:	2 kHz	Sm	all Signal BW:	10 MHz
Noise (e _{NI}):	240 nV/ $\sqrt{\text{Hz}}$	No	ise (e _{NI}):	$13 \text{ nV}/\sqrt{\text{Hz}}$
V _{OS} :	10 mV max	Vos	s:	100 mV
In-Amp Gain:	10	In-	Amp Gain:	10
Maximum Output		Ma	aximum Output	
Voltage Swing:	$\pm 4.7\mathrm{V}$	V	oltage Swing:	V_{CC} – 1.2 V, V_{CC} + 1.2 V
CMRR:	120 dB (dc to 60 Hz)	CN	ARR:	100 dB (dc to 60 Hz)
Nonlinearity:	20 ppm max	No	nlinearity:	40 ppm max
Supply Voltage:	$\pm 5 \mathrm{V}$	Sup	pply Voltage:	Dual, $\pm 5 \text{ V}$ to $\pm 12 \text{ V}$
Supply Current:	3.5 mA max	Sup	pply Current:	3 mA typ
Recommended ADI	ADC#1	0.0	1% Settling Time	
AD7942		fo	or 5 V step:	0.5 μs
Resolution:	14 bits	Re	commended ADI	ADC#1
Input Range:	5 V	AD	D7685, AD7687	
Sampling Rate:	250 kSPS	Res	solution:	16 bits
S/D Supply:	2.7 V to 5.25 V	Inp	out Range:	5 V
Power:	1.25 mW, 2.5 V supply	Sar	npling Rate:	250 kSPS
Recommended ADI	ADC#2	S/E	O Supply:	Single, 2.5 V to 5 V
AD7321		Pov	wer:	4 mW at 0.1 kSPS, 5V supply
Resolution:	13 bits	Re	commended ADI	ADC#2
Input Range:	$\pm 2.5\mathrm{V}$	AD	D7327, AD7323, an	d AD7321
Sampling Rate:	500 kSPS	Res	solution:	13 bits/12 bits
S/D Supply:	± 5 V to ± 15 V,	Inp	out Range:	$\pm 2.5 \mathrm{V}$
	2.7 V to 5.25 V	Sar	npling Rate:	0.5 MSPS
Power:	17 mW max at 500 kSPS	S/E	O Supply:	± 5 V to ± 15 V, single, 5 V
	with ± 15 V, 5 V supply	Pov	wer:	17 mW max at 500 kSPS
NOTE: Specifications are preli	minary. Refer to www.analog.com.			with ± 15 V, 5 V supply

NOTE: Specifications are preliminary. Refer to www.analog.com.

Table 7-2. Recommended ADCs for Use with ADIIn-Amps (continued)

ADI In-Amp Zero Drift In-Amp	AD8553RM	ADI In-Amp Zero Drift In-Amp	AD8555AR/AD8556ARZ
Small Signal BW: Noise (e _{NI}): V _{OS} : In-Amp Gain: Maximum Output Voltage Swing: CMRR: Nonlinearity: Supply Voltage: Supply Voltage: Supply Current:	1 kHz 150 nV/√Hz 50 mV max 10 0.075 V to 4.925 V 120 dB (dc to 60 Hz) 600 ppm max Single, 5 V 1.3 mA max ADC#1	Small Signal BW: Noise (e _{NI}): V _{OS} : In-Amp Gain: Maximum Output Voltage Swing: CMRR: Nonlinearity: Supply Voltage: Supply Current: 0 1% Settling Time	$ \begin{array}{r} 150 \text{ kHz} \\ 32 \text{ nV}\sqrt{\text{Hz}} \\ 10 \text{ mV max} \\ 10 \\ 30 \text{ mV to } 4.94 \text{ V} \\ 100 \text{ dB } (\text{G} = 70, \text{ dc} \\ to 200 \text{ Hz}) \\ 1000 \text{ ppm typ} \\ Single, 5 \text{ V} \\ 2.5 \text{ mA max} \\ \end{array} $
AD7476 Resolution:	12 hits	for 4V step:	8 ms
Input Range: Sampling Rate: S/D Supply: Power:	0 to V _{DD} 1 MSPS 2.35 V to 5.25 V 3.6 mW max at 1 MSPS with 3 V supply 15 mW max at 1 MSPS with 5 V supply	Recommended ADI AD7685 Resolution: Input Range: Sampling Rate: S/D Supply: Power:	ADC#1 16 bits 5 V 250 kSPS Single, 2.5 V to 5 V 4 mW at 0.1 SPS with
Recommended ADI	ADC#2		5 V supply
AD7466 Resolution: Input Range: Sampling Rate: S/D Supply: Power:	12 bits 0 to V _{DD} 100 kSPS 1.6 V to 3.6 V 0.62 mW max at 100 kSPS with 3 V supply 0.12 mW max at 100 kSPS with 1.6 V supply	Recommended ADI AD7476 Resolution: Input Range: Sampling Rate: S/D Supply: Power:	ADC#2 12 bits 0 to V _{DD} 1 MSPS 2.35 V to 5.25 V 3.6 mW max at 1 MSPS with 3V supply 15 mW max at 1 MSPS with 5 V supply
		Recommended ADI AD7476A Resolution: Input Range: Sampling Rate: S/D Supply: Power:	ADC#3 12 bits 0 to V _{DD} 1 MSPS 2.7 V to 5.25 V 3.6 mW max at 1 MSPS with 3 V supply 12.5 mW max at 1 MSPS

with 5 V supply



Figure 7-1. In-amp buffers ADC and provides dc correction.

High Speed Data Acquisition

As the speed and accuracy of modern data acquisition systems have increased, a growing need for high bandwidth instrumentation amplifiers has developed particularly in the field of CCD imaging equipment where offset correction and input buffering are required. Here, double-correlated sampling techniques are often used for offset correction of the CCD imager. As shown in Figure 7-1, two sample-and-hold amplifiers monitor the pixel and reference levels, and a dc-corrected output is provided by feeding their signals into an instrumentation amplifier.

Figure 7-2 shows how a single multiplexed high bandwidth in-amp can replace several slow speed nonmultiplexed buffers. The system benefits from the common-mode noise reduction and subsequent increase in dynamic range provided by the in-amp.



Figure 7-2. Single high speed in-amp and mux replace several slow speed buffers.

Previously, the low bandwidths of commonly available instrumentation amplifiers, plus their inability to drive 50 Ω loads, restricted their use to low frequency applications—generally below 1 MHz. Some higher bandwidth amplifiers have been available, but these have been fixed-gain types with internal resistors. With these amplifiers, there was no access to the inverting and noninverting terminals of the amplifier. Using modern op amps and employing the complementary bipolar (CB) process, video bandwidth instrumentation amplifiers that offer both high bandwidths and impressive dc specifications may now be constructed. Common-mode rejection may be optimized by trimming or by using low cost resistor arrays. The bandwidth and settling time requirements demanded of an in-amp buffering an ADC, and for the sample-and-hold function preceding it, can be quite severe. The input buffer must pass the signal along fast enough so that the signal is fully settled before the ADC takes its next sample. At least two samples per cycle are required for an ADC to unambiguously process an input signal (FS/2)—this is referred to as the Nyquist criteria. Therefore, a 2 MHz ADC, such as the AD7266 or AD7322, requires that the input buffer/sample-and-hold sections preceding it provide 12-bit accuracy at a 1 MHz bandwidth. Settling time is equally important: the sampling rate of an ADC is the inverse of its sampling frequency-for the 2 MHz ADC, the sampling rate is 500 ns. This means that for a total throughput rate of less than 1 μ s, these same input buffer/sample-and-hold sections must have a total settling time of less than 500 ns.

A High Speed In-Amp Circuit for Data Acquisition Figure 7-3 shows a discrete in-amp circuit using two AD825 op amps and an AMP03 differential (subtractor) amplifier. This design provides both high performance and high speed at moderate gains. Circuit gain is set by resistor R_G where gain = $1 + 2 R_F/R_G$. The R_F resistors should be kept at around 1 k Ω to ensure maximum bandwidth. Operating at a gain of 10 (using a 222 Ω resistor for R_G) the -3 dB bandwidth of this circuit is approximately 3.4 MHz. The ac common-mode rejection ratio (gain of 10, 1 V p-p common-mode signal applied to the inputs) is 60 dB from 1 Hz to 200 kHz and 43 dB at 2 MHz. And it provides better than 46 dB CMRR from 4 MHz to 7 MHz. The RFI rejection characteristics of this amplifier are also excellent—the change in dc offset voltage vs. common-mode frequency is better than 80 dB from 1 Hz up to 15 MHz. Quiescent supply current for this circuit is 15 mA.

For lower speed applications requiring a low input current device, the **AD823** FET input op amp can be substituted for the AD825.

This circuit can be used to drive a modern, high speed ADC such as the **AD871** or **AD9240**, and to provide very high speed data acquisition. The AD830 can also be used for many high speed applications.



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Figure 7-3. A High performance, high speed in-amp circuit.